GEOLOGIC AND TECTONIC FEATURES OF THE COYOTE MOUNTAINS, ARIZONA

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The granitic rocks of the Coyote Mountains in south central Arizona exhibit a well defined planar structure which strikes to the northwest and dips steeply to the southwest. The range was examined in an attempt to cast some light on the character of the granitic rocks in this part of the state and to determine the configuration of their internal structures. Previous work in the area by McGee (1897), Bryan (1922, 1923) and Darton (1925) has been largely confined to descriptions of topography and analyses of sedimentary processes in arid regions. This paper proposes to describe briefly the rocks and tectonic fabric of this hitherto relatively unknown part of southern Arizona.

LOCATION AND DESCRIPTION

The Coyote Mountains are located 30 miles west of Tucson, at the northern extremity of the Baboquivari chain. The Baboquivari Mountains trend northward from the Mexican border essentially following the 111° 40′ meridian for a distance of more than 30 miles and are one of a group of sub-parallel ridges in southern Arizona.

The Coyote Mountains mass is roughly triangular in plan (fig. 1). Steep, rugged slopes are common and much of the area is virtually inaccessable. The highest point is Coyote Peak which lies in the northwestern part of the mapped area. Relief is approximately 3300 ft. and plan area exceeds 22 sq. mi.

Folded volcanic rocks of the Roskruge Mountains lie to the northeast of the Coyote Mountains, and granitic rocks belonging to the Quinlan group are found to the west. Both the Roskruge and Quinlan ranges are separated from the Coyote Mountains by major faults which are reflected in the topography of the area by steep, eroded scarps and low passes.

THE ROCKS

General statement. Metamorphic and igneous rocks of several types are exposed in the Coyote Mountains, and a brief description of each type is included below, although a thorough discussion of the petrology and petrography of these rocks is not within the scope of this paper. Suffice it to say that many of the varieties mentioned, when examined in thin section, reveal highly irregular mineral borders, mineral overgrowths, and numerous tiny inclusions, all of which are indicative of crystalloblastic growth and perhaps of additive metamorphism. Shearing, crushing, and evidence of recrystallization are to be seen in some of the specimens (especially the alaskites), indicating that the rocks have undergone one or more phases of dynamic metamorphism. Although an origin by granitization for some of these rocks has not been proven, the petrographic features just mentioned as well as the evidence afforded by the arrangement of internal structures indicates that the process should not be ruled out.

Sedimentary rocks. Red shales, conglomerates, and siltstones, tentatively correlated with the Cretaceous (?) Recreation red beds (Brown, 1939) crop out along the Ajo Road fault zone and probably underlie portions of the Roskruge Mountain extrusives farther north. Within the Coyote Mountains, the only direct evidence of a former sedimentary rock is the presence of marble and quartzite masses which are now surrounded by diorite.

Monzonite. Rocks of undetermined origin, which have compositions ranging from granite through monzonite to quartz diorite, occupy most of the southern

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and eastern portions of the Coyote Mountains. All these rocks are shown as monzonite on figure 1. Inclusions of hand sized clots of biotite-rich schistose rock are common throughout most of the monzonite and related rock types. The orientation of these clots, as well as the orientation of biotite flakes, hornblende crystals, and feldspar porphyroblasts, contribute to the planar structure conspicuous in these rocks.

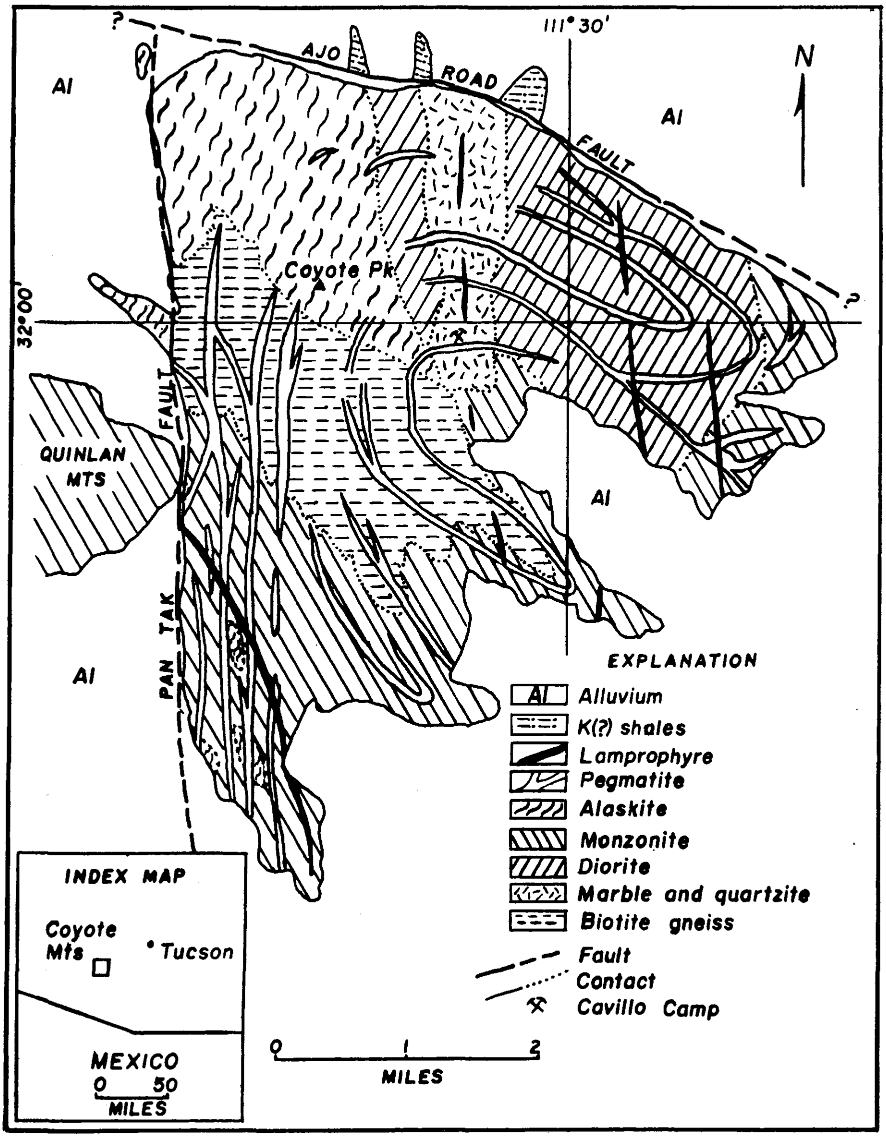


FIGURE 1. Geologic map of the Coyote Mountains, Arizona.

Pegmatite. Pegmatite is widespread throughout most of the mountain mass. The occurrences can be grouped into three classes: (1) tabular, dike-like bodies dipping 20°–30° east to southeast, some of which are as much as 80 ft. thick, (2) irregular, anastomosing veinlets as much as one foot thick, which probably represent stringers from the larger masses, and (3) diffuse masses of pegmatite which literally "soak" the enclosing rock. The mineralogy of the pegmatite is relatively simple—quartz, orthoclase and plagioclase with minor biotite, muscovite and red garnet. Large crystals of perthitic orthoclase are common. The northwest strike of planar elements is retained in blocks of biotite gneiss and monzonite that

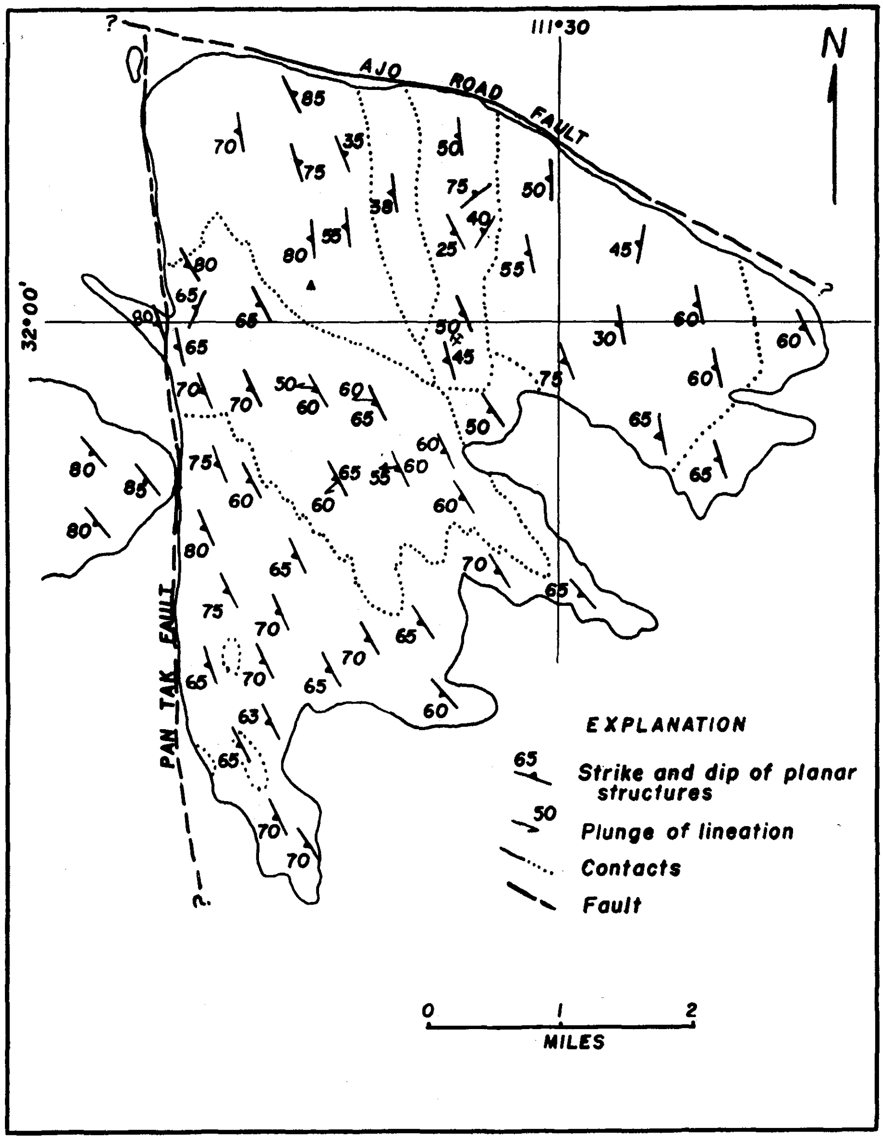


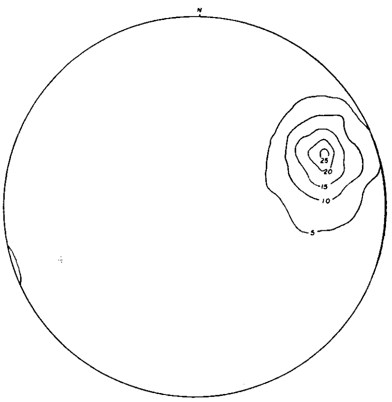
FIGURE 2. Tectonic map of the Coyote Mountains, Arizona.

have been included between the larger pegmatite bodies, and the blocks do not appear to have been displaced or rotated. In some places the planar elements found in the enclosing rocks can be traced into the pegmatite. In figure 1 the pegmatite outcrops are generalized and the unusual pattern is a reflection of the effect of rugged topography on shallow dipping layers.

Biotite gneiss. A northwest striking band of biotite gneiss approximately one and one-half miles wide is found in the central portion of the Coyote Mountains mass. The rock is a typical fine-grained biotite-orthoclase-quartz gneiss, which in part grades into a flaky biotite schist. The contact between the gneiss and the surrounding rocks is sharp, but extremely irregular. Near the alaskite the gneiss is bleached and somewhat altered, and contacts are less distinct. The largest of the tabular pegmatite bodies cut the biotite gneiss.

Alaskite. Rocks mapped as alaskite and consisting mainly of quartz and orthoclase crop out in the northwestern part of the Coyote Mountains and in scattered locations to the south (fig. 1). The largest mass of alaskite is strongly sheared, and thin sections of the rock show extreme rounding of feldspars as well as recrystallization of quartz with attendant flamboyant extinction patterns. Where-

FIGURE 3. Equal-area projection of the perpendicular poles of planar structures, Coyote Mountains, Arizona. 300 readings, 5% contours. Plotted on the lower hemisphere.



ever biotite is found, a crude planar orientation can be seen and the attitude of the planes of shearing is revealed. Minor, flat-lying shear planes are found near the Ajo Road fault. The outcrops of alaskite found in the southern portion of the range do not show this shearing.

Diorite. Rocks ranging in composition from diorite to gabbro, with some small masses of hornblendite are located in the northern portion of the mapped area. Planar structures in the diorite are formed by preferentially oriented biotite flakes and hornblende crystals within the rock mass. The diorite encloses the elongate block of metamorphosed sediments described below, and both are cut by lamprophyre dikes and pegmatite masses, the largest of which are shown on figure 1.

Marble and Quartzite. Banded, impure marbles and quartzites are located in the central part of the Coyote Mountains. Where bedding planes are recognized in these rocks, they seem to parallel the trend of the planar elements found in the surrounding rocks, although the erratic attitudes of these bedding planes in the center part of the band suggests folding and/or rotation of small fault blocks. Garnet, diopside and epidote (clinozoisite?) are present in moderate amounts. Attitudes of planar structures in the marble and quartzite have not been included in the equal-area plot (fig. 3).

Copper-tungsten deposits of minor consequence are found in the Cavillo Camp mining area. The ore minerals occur as fracture fillings and replacements in the metamorphosed sediments.

Dike Rocks. In addition to the rocks described above, numerous small dikes of lamprophyre and rhyolite are found throughout the region. Generally, the dikes strike north to northwest, but dip more steeply than the planar structures in the enclosing rocks. These dikes cut across all other rocks and are thought to represent the latest phase of igneous activity in the area.

INTERNAL STRUCTURES

Internal structures in the rocks of the Coyote Mountains are manifest in oriented hand-sized clots of a biotite-rich schistose rock and in oriented flakes of biotite, crystals of hornblende and porphyroblasts of feldspar. Generally these elements indicate a well developed planar structure in all the major rock types, with the exception of the pegmatite and the dikes. Lineation in the plane of foliation is noted in the biotite gneiss and rarely in the alaskite, but recognizable linear structures appear to be absent in the other rocks. Planar structures in the alaskite are less noticeable owing to the virtual absence of dark clots and biotite flakes.

The tectonic map (fig. 2) indicates a persistent trend of planar structures within the Coyote Mountains. An equal-area plot of the perpendicular poles of planar structures is shown in figure 3, and the contoured distribution serves to emphasize the persistence of a northwest trend. An average strike and dip reading is approximately N 24° W, 64° SW.

Folding can be recognized in the vicinity of the major faults that bound the mountain range on two sides. Localized buckling of the biotite gneiss near the Pan Tak fault on the west side of the range has produced folds with steeply plunging axes. Most of these folds apparently are the result of drag along the Pan Tak fault, which intersects the planar elements of the gneiss at an acute angle. The presence of these folds, coupled with the gradual swing of other planar elements into parallelism with the fault and the dragging effect observed on the alaskite dike west of the fault, indicate a strike-slip component to the faulting, with the Coyote Mountains block moving relatively southward.

Owing to the lack of exposures and general absence of well developed planar structures, the nature of the movement along the Ajo Road fault has not been determined. Presence of Cretaceous (?) sediments to the north indicates that the mountain block has been thrust upwards, but no concrete evidence of strike-slip movement was observed. Planar structures in the diorite cut by the Ajo Road fault imply movement to the northeast while those in the alaskite suggest a movement in the opposite direction.

The topography along the southeast face of the Coyote Mountains further reflects the trend of planar elements. A glance at figure 1 shows that the canyons and ridges along the southeastern extremity of the range roughly parallel the strike of the planar structures found in the rest of the mountain mass.

Joints. Joints are not a conspicuous feature in most parts of the Coyote Mountains. The attitude of widely spaced joint planes has controlled erosion on the north face of Coyote Peak, and the appearance, as noted by Bryan (1923), is that of a large tilted block of bedded sediments. Elsewhere the joint sets are less spectacular. Generally the joints strike to the northeast, cutting the trend of planar elements at almost right angles. Joints are best developed in the finer grained rocks, and the joint planes usually die out as they pass into the coarser grained rocks. Exfoliation of the granitic rock has produced massive domes in the vicinity of the Cavillo Camp mining area.

AGE OF THE ROCKS

The geologic age of the Coyote Mountains rocks and their structure has not been determined. The following items, however, may have a bearing on the solution of this problem.

A comparison with pre-Cambrian trends elsewhere in southern Arizona reveals that the Coyote Mountains planar structures strike almost at right angles to the trend of normal pre-Cambrian structures. Several possibilities for such an occurrence present themselves, among which are: (1) the Coyote Mountains represent a broad fold in the pre-Cambrian terrain, (2) the Coyote Mountains block has been rotated into its present position, or (3) the structures, and possibly the rocks are not pre-Cambrian.

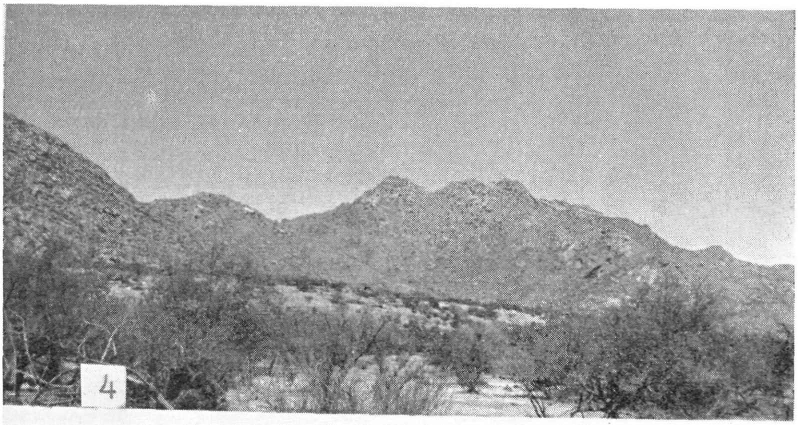


FIGURE 4. General view of the Coyote Mountains. The white patches are pegmatite dikes.

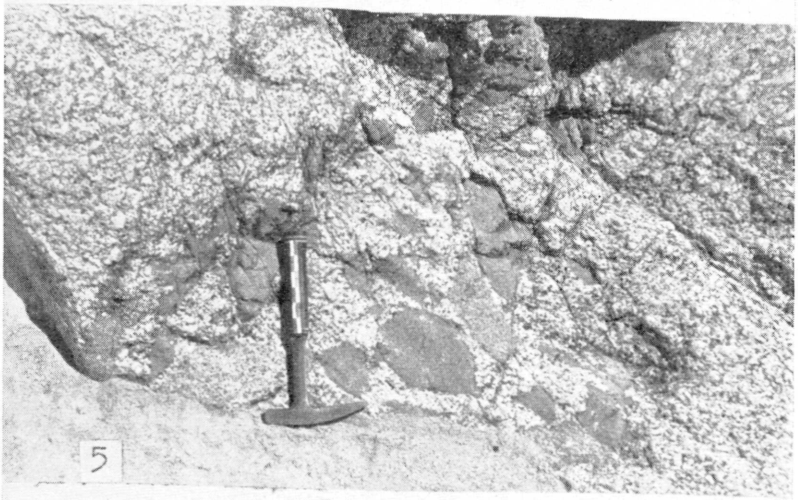


FIGURE 5. Swarm of small dark clots in the monzonite. View is taken normal to the strike of the clots. Marks on hammer handle are one inch long.

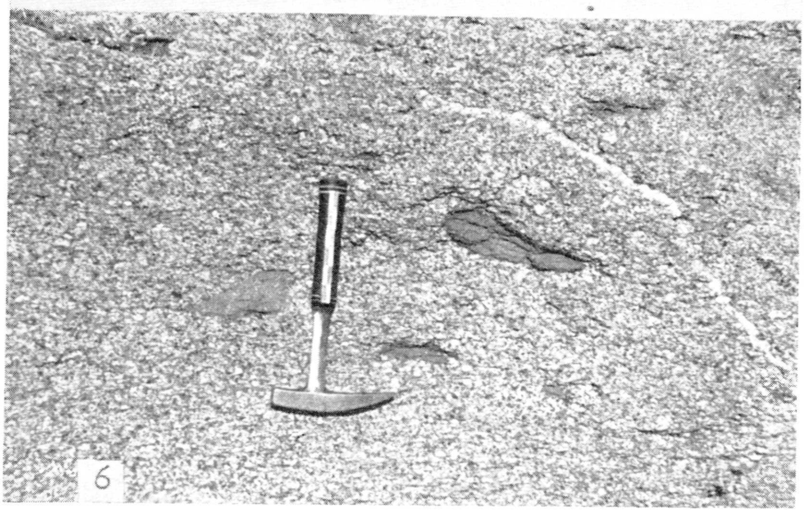


FIGURE 6. Close-up of small clot in coarse grained monzonite. The small white streak is a pagmatite veinlet.

The general uniformity of orientation of planar elements over the whole Coyote Mountains block, as well as in parts of the range to the west (fig. 2), weakens the first argument. The final test of this premise would require the examination of the structures in the rocks farther west and south to determine whether or not a fold existed. From the information at hand, which is based on a study of the Coyote and part of the Quinlan mountains, it does not appear that these rocks represent a flexure in a pre-Cambrian terrain.

That some rotation has occurred, especially along the Pan Tak Fault, is inferred from the fact that planar structures west of the fault strike 5 to 10 degrees more to the northwest and have steeper dips than those to the east. However, rotation on a scale sufficient to cause an 80° to 90° change in strike direction has not been recognized.

The suggestion that the majority of the rocks, or at least their internal structures (if the two are not of the same age), are younger than pre-Cambrian is based on the presence of possible Paleozoic metamorphosed sediments in the area, and on the suggestions made by other workers who have conducted studies in this part of the state. Although no fossils have been found, the metamorphosed limestone beds previously mentioned bear a strong likeness to limestones of probable Paleozoic age in the Tucson and Sierrita Mountains to the east (Brown, 1939, Ransome, 1921). Since the Coyote Mountains marbles and associated metasediments appear to be a block partially engulfed by dioritic rocks of undetermined origin, these surrounding rocks may be younger than pre-Cambrian and possibly younger than Paleozoic. Furthermore, the recognition at Bisbee (Butler and Wilson, 1938) and at Ajo (Gilluly, 1937) of Mesozoic tectonic activity seems to link the Coyote Mountains rocks and their structures to the tectonic events of that era. Paleotectonic and paleogeologic maps of the Late Jurassic presented by Eardley (1951) include the area in the vicinity of the Coyote Mountains in the Chico Shuni orogenic belt, the tectonic activity in which is provisionally correlated with that of the Nevadan Revolution.

Summarizing these last few points, it seems that an age younger than pre-Cambrian should be considered for the Coyote Mountains rocks and their internal structures because of:

1. Nonconformity of structural trends in the Coyote Mountains with normal northeast pre-Cambrian trends found in other parts of southern Arizona.
2. Presence of metamorphosed sediments which may be of Paleozoic age.
3. Known orogenic activity capable of producing the Coyote Mountains rocks and their structures, which activity is generally assigned to the Mesozoic era.

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